IDA

INSTITUTE FOR DEFENSE ANALYSES

The Relationship Between Training and Unit Performance for Naval Patrol Aircraft – Revised

Colin P. Hammon
Stanley A. Horowitz, Project Leader

December 1996

IDA Paper P-3139
(Revised)

Log: H 96-004200

This work was conducted under contract DASW01 94 C 0054, Task T-L7-516, for the Office of the Assistant Secretary of Defense (Personnel and Resources). The publication of this IDA document does not indicate endorsement by the Department of Defense, nor should the contents be construed as reflecting the official position of that Agency.

INSTITUTE FOR DEFENSE ANALYSES

IDA Paper P-3139
(Revised)

The Relationship Between Training and Unit Performance for Naval Patrol Aircraft – Revised

Colin P. Hammon
Stanley A. Horowitz, Project Leader

PREFACE

This paper was prepared by the Institute for Defense Analyses (IDA) for the Office of the Under Secretary of Defense (Personnel and Readiness) under a task entitled "Improved Methodologies for Relating Flying Hour Activity to Operational Readiness and Safety Measures." The objective of this portion of the task was to facilitate development of quantitative relationships between the capability of aviation units to perform their assigned missions and the levels of training resources available to them.

This work was reviewed within IDA by Bruce N. Angier, Jesse Orlansky, and John C. Tillson.

CONTENTS

FIGURES

TABLES

EXECUTIVE SUMMARY

The flying hour program is the key element in air crew continuation training, but there is considerable uncertainty about the value of maintaining flying hours at the current level. Flying hours are an attractive target for congressional budget reductions because money can be saved immediately. With lower international tensions and the accompanying reduction of military forces, there will be a tendency to reduce flying hour programs. In this environment, it is important to have a better idea of just what the implications of possible reductions in flying hours are for the performance of United States military air crews and for our ability to effectively mobilize aviation assets.

This report develops quantitative relationships between how much air crews fly and how well they perform important aspects of their missions. The current study is the latest in a series of statistical analyses that examines both the long-term and short-term effects of flying hours on performance. The previous studies examined four aviation missions or skill areas:

- the quality of F-14 and A-7 aircraft landings aboard aircraft carriers;
- the accuracy with which Marine aviators dropped bombs from AV-8B, F/A-18, and F-4S aircraft;
- the performance of F-14 fighters during opposed air-combat-maneuvering exercises on an instrumented range;
- Marine Corps bombing using a larger database; and
- Air Force C-130 tactical airdrops.

The last two investigations also examined the contribution of simulator training to air crew performance. Simulator training was found to make a significant, cost-effective contribution to performance. The findings confirmed the existence of both short- and long-term positive effects of flying hours on air crew performance. In addition, the relative magnitude of these effects was estimated.

This study examines the performance of Navy Patrol air crews and extends the previous work in important ways. The data were derived from graded torpedo attack exercises (Torpexes) flown on an instrumented range. The nature of the Torpex, a competitive exercise required for crew qualification, is such that it tests the crew members in several aspects of the maritime patrol mission. The aircraft enters the

exercise area with the target submerged. The crew must detect, classify, track, and successfully launch an exercise torpedo in order to qualify in the exercise. In addition, the P-3 used for the patrol mission is a multiperson aircraft, and it was possible to isolate the training effects on the total mission performance of different crew members.

The crew members of primary interest to this analysis comprise the Tactical Nucleus (TACNUC), which consists of two officers, the aircraft commander (AC) and the tactical coordinator (TACCO), and two enlisted members, the first acoustic operator (S1) and the electronic warfare operator (S3). The aircraft commander is a Naval Aviator responsible for flight operations and safety of flight. If designated as the mission commander, he is also responsible for the conduct of the overall tactical mission. The TACCO is a Naval Flight Officer (NFO) responsible for keeping track of the total tactical picture and coordinating the work of the other members of the crew. His station is the nerve center of the aircraft, where information is displayed, analyzed and interpreted. Either the AC or the TACCO may be designated Mission Commander. The acoustic operator uses acoustic processing equipment that displays and assists in the interpretation of sonobuoy information to detect, classify, and localize targets. The electronic warfare operator uses radar or electronic countermeasures (ECM) equipment for early target detection and Magnetic Anomaly Detection (MAD) equipment for final target localization.

DATA

Performance data were obtained from Patrol Wing Five at Brunswick Naval Air Station, Maine. Flying hour and simulator training data were obtained from daily flight records and pilot and NFO career flying-hour summaries maintained by the Sea Logistics Center at Mechanicsburg, Pennsylvania. The database includes mission performance data and flight and simulator experience data for pilots, TACCOs, acoustic operators, and electronic operators from five operational squadrons flying P-3 aircraft on torpedo attack exercises. Career and daily flying hours were available for pilots and TACCOs. Only daily flight and simulator records were available for enlisted crew members. Performance data were obtained for 56 Torpex missions. Twenty-one percent of these were flown against an actual submarine, and the remainder were flown against a MK 30 target simulator.

ANALYSIS

The central hypothesis of this analysis is that training improves performance. Thus, crew members with more career flight and simulator hours are expected to detect, localize and track the target with greater proficiency, and place their torpedoes more accurately. We also hypothesize that, holding career training experience constant, increases in recent flying and simulator experience are associated with more accurate attacks.

These hypotheses were tested using a Cobb-Douglas production function formulation. To gain additional insight into the effect of experience on Torpex scores, we also formulated the model in the form of a generalized translog production function. We hypothesize that interactions exist (1) between flying hours and simulator hours and (2) between long-term and short-term variables. The latter formulation turned out to provide the better estimates.

FINDINGS AND CONCLUSIONS

The findings of the current study confirm the existence of both short- and long-term positive effects of flying hours and short-term effects of simulator hours on air crew performance. The results are consistent with previous studies, in that the long-term effect is stronger than the short-term effect. We were unable to examine long-term flying or simulator effects for the enlisted crew members because of data limitations. We were able to estimate the effect on performance of air crew simulator hours for the previous 30 days.

Table S-1 summarizes the impact on performance of a 10% decrease in flying hours from the then-current levels.

Table S-1. Decrease in Performance (Torpex Score) for 10% Decrease in Three Measures of Flying/Simulator Experience

	Career Flying Hours	Recent Flying Hours	Recent Simulator Hours
Pilot Aircraft Commander	0.4%	—	—
TACCO Mission CDR	0.2%	—	—
First Acoustics Operator	—	0.04%	0.2%[a]
Total	0.6%	0.04%	0.2%

[a] Because the TACCO, First Acoustics Operator and Electronics Operator fly and exercise in the simulator as a crew the short-term effects of these three could not be estimated together. We interpret the results for the First Acoustics Operator as the crew effect.

- Existing data on performance can be used to develop relationships between air crew performance and both long- and short-term experience variables that reflect the impact of variations in the flying hour program.
- Maritime patrol Torpex scores are influenced by the number of career aircraft commander hours of the pilot, mission commander hours of the TACCO, and recent flying hours of the acoustic operator.
- This finding that long-term effects are quantitatively more important than short-term effects implies that it may be unwise to reduce overall air crew experience with the thought that, when needed, crews can be brought to full effectiveness with a short period of intensive training.
- A 10% reduction in flying hours, both career and recent, is estimated to decrease Torpex scores by a little more than 0.6%.
- On the margin, the partial effect of recent simulator hours—that is, the effect on proficiency of one simulator hour more or less—is greater than that of short-term flying hours. (The table shows that a 10% change in recent flying has a greater impact than a 10% change in recent simulator use, but 10% amounts to many more flight hours than simulator hours). This indicates that the additional use of simulators would be cost effective.
- This analysis is important because it demonstrates our ability to estimate the effect of flying and simulator hours on performance over nearly the full range of the maritime patrol mission—detection, classification, tracking, and attack.
- Because of multicollinearity, we were unable to disentangle the effects of all of the variables. In particular, we were unable to completely disentangle the individual effects of each member of the TACNUC. We conjecture that this stems from the fact that the TACCO, S1, and S3 fly and train in the simulator together. We were therefore able to sort out the short-term variables in terms of the total crew.
- We cannot predict the total long-term effect of additional flying because of the absence of enlisted career flying hour data.
- The data used in this study reflect operations before the collapse of the Soviet Union, when maritime patrol squadrons averaged approximately 45 flying hours per month per crew over the entire 18-month training cycle. This has been reduced to as little as 30 hours per month. We would expect the quantitative findings to be different for current data.
- It would appear to be worthwhile to analyze the data generated under the current flying hour levels. It is too great a leap to extrapolate our findings to a 33% decrease in flying hours (45 to 30 hours per month per crew). An experiment using current data could greatly increase our understanding of the effect of marginal changes in career flying hours and both short-term flying

and simulator hours on Torpex scores. A more complete data set would be available provided the assistance of the wing and squadrons was enlisted for a period of approximately 1 year. With more complete records, including enlisted career flying hours and a complete record of crews for every competitive exercise, many of the problems with the current data could be eliminated. Other data problems, such as the lack of career TACCO and enlisted simulator hours, would require a major change in Navy record keeping procedures over a longer period of time.

RECOMMENDATIONS

We recommend that controlled experiments be conducted and a more complete database constructed to perform the following:

- studies designed to gain a better understanding of the cost-effectiveness implications of changes in flying hour budgets for different missions, aircraft types, and crew positions.
- analyses aimed at further documenting the marginal effects of changes in simulator and actual flying hours on performance at current and projected levels.

To better understand the full potential costs of reduced air crew training, the results of studies such as this one should be incorporated into combat analyses.

Our final recommendation is to consider the following policy actions:

- Moving to a more senior mix of personnel. This could involve encouraging longer careers, perhaps by modifying retirement policies and incentives.
- Keeping individuals with hard-to-train operational skills, such as pilots, in operational billets as much as possible, consistent with the need for trained and educated leaders.
- Making use of experienced personnel through maximum practical reliance on the reserve components (particularly in aviation) should be encouraged.

I. INTRODUCTION

The flying hour program is the key element in air crew continuation training, but there is considerable uncertainty about the value of maintaining flying hours at the current level. Flying hours are an attractive target for congressional budget reductions because money can be saved immediately. Over $10 billion a year are spent on the flying hour programs of all services. With lower international tensions and the accompanying reduction of military forces, there will be a tendency to reduce flying hour programs. In this environment, it is important to have a better idea of just what the implications of possible reductions in flying hours are for the performance of United States military air crews and for our ability to effectively mobilize aviation assets.

This paper develops quantitative relationships between how much air crews fly and how well they perform important aspects of their missions. The current study is an extension of statistical analyses reported in references [1] and [2]. The referenced analyses examined both the long-term and short-term effects of flying hours on performance. Five empirical investigations examined four aviation missions or skill areas:

- the quality of F-14 and A-7 aircraft landings aboard aircraft carriers,
- the accuracy with which Marine aviators dropped bombs from AV-8B, F/A-18, and F-4S aircraft,
- the performance of F-14 fighters during opposed air-combat-maneuvering exercises on an instrumented range,
- Marine Corps bombing using a larger database, and
- USAF C-130 tactical airdrops.

Reference [2] also examined the contribution of simulator training to air crew performance. Simulator training was found to make a significant, cost-effective contribution to performance. The findings confirmed the existence of both short- and long-term positive effects of flying hours on air crew performance. In addition, the relative magnitude of these effects were estimated. Table I-1 summarizes the impact on performance of a 10% decrease in flying hours from the then current levels, based on the analyses in references [1] and [2]. All the effects shown in the table are statistically significant.

Table I-1. Decrease in Performance for 10% Cuts in Four Measures of Flying/Simulator Experience

Performance Measure	Career Flying Hours	Recent Flying Hours	Total Flying Hours	Career Simulator Hours
Unsatisfactory Landings[a]	6.9%	2.6%	9.5%	—
Air-to Air Combat[a,b]				
Probability Red Kills Blue	6.3%	2.9%	9.2%	—
Probability Blue Kills Red	-2.6%	-2.2%	-4.8%	—
Marine Bombing Miss Distance[c]	1.2%	0.6%	1.8%	0.3%
C-130 Tactical Airdrop Miss Distance[c]				
Copilot	0.5%	—	0.5%	1.0%
Navigator	—	2.3%	2.3%	—
Total	0.5%	2.3%	2.8%	1.0%

a Source: Reference [1].
b Red are aggressor aircraft; Blue are friendly aircraft. The flying hour decrease is only for Blue air crews.
c Source: Reference [2].

This study reports the results of additional statistical analyses of both the long- and short-term effects of flying hours and simulator hours on performance. This analysis examines the performance of Navy Patrol air crews and extends the previous work in important ways. The data were derived from graded torpedo attack exercises (Torpexes) flown on an instrumented range. The Torpex, a competitive exercise which is required for crew qualification, tests the crew members in several aspects of the maritime patrol mission. The aircraft enters the exercise area with the target submerged. To qualify in the exercise, the crew must detect, classify, track, and successfully launch an exercise torpedo. The P-3 used for the patrol mission is a multiperson aircraft; it was possible to isolate the training effects on total mission performance of different crew members.

Our findings confirm the existence of both short- and long-term positive effects of flying hours and short-term effects of simulator hours on air crew performance. Because of data limitations, we were unable to examine the long-term flying or simulator effects for the enlisted crew members. We were able to estimate the effect on performance of air crew simulator hours for the previous 30 days.

A description of the data, the analyses, and findings are presented in Chapter II. Conclusions and recommendations are stated in Chapter III.

II. ANALYSIS OF NAVY PATROL AIRCRAFT TORPEDO ATTACK EXERCISES

This chapter reports the results of an investigation of the relation between P-3 air crew training, measured by flying and simulator hours, and performance in detecting, classifying, tracking, and attacking submarines and simulated targets. This analysis treats a multi-person mission, and we were able to estimate the contribution of short-term simulator hours to mission performance, which had not been possible in our earlier work. When mission performance depends on more than one person, it is generally more difficult to isolate the effect of experience of each crew member on crew performance. For this analysis, we were able to separate the training effects of the pilot from those of the tactical coordinator and acoustic equipment operator. Further, the performance data capture the output of the training process far more completely than some of the measures that have been used in the past (Marine air-to-ground miss distance, for example).

A. DESCRIPTION OF THE AIRCRAFT AND CREW

The Navy Maritime Patrol aircraft is the P-3 Orion, a long-range land-based multi-engine aircraft that is manned on operational missions by a crew of approximately twelve—five officers and seven enlisted personnel. Crews are organized for maximum stability and once assigned to a crew, personnel generally remain with that crew for the duration of their squadron tour. The training cycle is approximately 18 months, with the squadron being deployed during the last 6 months of the cycle. Crews are formed in the early part of this cycle and fly together during the work-up period and subsequent deployment.

The crew members of primary interest to our analysis comprise the Tactical Nucleus (TACNUC), which consists of two officers, the aircraft commander (AC) and the tactical coordinator (TACCO), and two enlisted members, the first acoustic operator (S1) and the electronic warfare operator (S3). The aircraft commander is a Naval Aviator responsible for flight operations and safety of flight. The TACCO is a Naval Flight Officer (NFO) responsible for keeping track of the total tactical picture and coordinating the work of the other members of the crew. His station is the nerve center of the aircraft, where information is displayed, analyzed, and interpreted. Either the AC or the TACCO may be designated Mission Commander with overall responsibility for the mission. The

acoustic operator uses acoustic processing equipment that displays and assists in the interpretation of sonobuoy information to detect, classify, and localize targets. The electronic warfare operator uses radar or electronic countermeasures (ECM) equipment for early target detection and Magnetic Anomaly Detection (MAD) equipment for final target localization.

Precise coordination is required among all members of the crew; the members of the TACNUC are key to the tactical operation and can limit the capability of the overall crew. Members of the TACNUC must be aboard and manning their assigned crew positions when certain critical events, called Competitive Exercises (COMPEXs), are flown. These exercises are graded by the wing staff and contribute to the crew and squadron readiness rating. When one member of the TACNUC is transferred, all other crew members lose their COMPEX qualifications and must re-qualify with the transferee's replacement. For each member of the TACNUC, there is at least one backup crew member who is in training for his position. The copilot is in training for AC, the navigator—an NFO—is in training as TACCO, and the second acoustics operator (S2) is in training for the S1 position. The S2 may also be in training for the S3 position, and each crew may have other enlisted trainees assigned who are in training for the S1, S2, or S3, positions. If a member of the TACNUC is due to be rotated during the training cycle, his backup generally qualifies in the TACNUC position for all exercises which require qualification as a crew. The backup crew member can then be designated as part of the TACNUC at the appropriate time without loss of crew readiness points.

B. DATA

Data for this study were obtained from Patrol Wing Five at Brunswick Naval Air Station, Maine. The database includes mission performance data and experience data for pilots, TACCOs, acoustic operators, and electronic operators from five operational squadrons flying P-3 aircraft on torpedo attack exercises. The missions were Torpexes, flown for TACNUC qualification, on an instrumented range located in either the Roosevelt Roads, Puerto Rico, or Key West operating areas.

The grading of torpedo attacks is more complicated than for the bomb or rocket launches analyzed in previous studies. For those analyses, the miss distance was used as the measure of performance. For Torpexes, the course and speed of the target as well as the placement of the torpedo and aircraft heading must be taken into account. The probability of a hit (P_h) is calculated by range personnel, and depends on the distance between the torpedo's point of entry into the water and the target as well as the angle

between the entry point and the target course. The P_h also depends on how closely the crew estimates the target speed. The drop score is calculated from the probability of hit.[1]

Crew qualification requires satisfactory performance in:

- Weapons management—Weapon properly loaded, and all settings correct and properly reported in the firing report.
- Localization/Tracking—Localize target and track for a minimum of 30 minutes prior to initial attack.
- Attack criteria:
  - Target tracked to attack criteria at time of each attack
  - All torpedoes launched within weapon parameters
- Attack effectiveness:
  - The crew attains a minimum score of 13. Points are calculated as follows:
    For the first attack the number of points equals 10 times the probability of hit calculated by range personnel. For each subsequent attack up to a total of four, the number of points equals five times the probability of hit. A minimum of two and a maximum of four attacks may therefore be flown to attain qualification, and the maximum number of points attainable is 25.
  - In the absence of the above scoring criteria, range Operations confirms that the torpedo acquired the target.

For this study all participants flew four attacks. Therefore, the number of points is a measure of the sum of the probability of hit for all attacks. Flying hour and simulator training data were obtained from daily flight records and from pilot and NFO career flying-hour summaries maintained by the Sea Logistics Center at Mechanicsburg, Pennsylvania. The data base is maintained as part of the Naval Flight Information Reporting System (NAVFLIRS). NAVFLIRS is an automated computer data base which includes the flight-hour history of all pilots and NFOs by year, aircraft type and model, and individual flight records for all air crew personnel by squadron and sortie. Pilot daily flight and career data include pilot and aircraft commander hours, night hours, instrument hours, and simulator hours. Daily and career flight hours, mission commander hours, and night hours are recorded for NFOs. Simulator hours are maintained on the daily

---

1 Only 30% of the torpedoes were functional exercise torpedoes (EXTORPS). The remainder were shapes, called REXTORPS. (REXTORPs have the same air-drop characteristics as an actual torpedo, but do not run after water entry). However, the type of torpedo used should not affect the score.

NAVFLIRS records for NFOs, but are not transferred to the career files. Only daily flight and simulator records are maintained in the NAVFLIRS data base for enlisted crew members. Career flight-hour totals are recorded in each enlisted crew member's log book, but these stay with the individual so were not available for crewmen who were no longer in the squadron when the data were collected.

Flight and simulator histories for the previous 7, 30, and 60 days were constructed from the daily flight records. Although daily flight data are recorded by individual by aircraft, it is not possible to tell who is actually occupying each crew station from the daily flight record. This was determined from available monthly crew lists published by each squadron.

Performance data were obtained for 56 Torpex missions. Twenty-one percent of these were flown against an actual submarine, and the remainder against a MK 30 target simulator. A target simulator, which looks like a small torpedo, electronically generates acoustic and magnetic signatures similar to those of a submarine. Target simulators are programmed to follow a pre-set track and may be capable of reacting to active acoustic detection equipment, depending on the model.

Table II-1 is a summary of the data used in the analysis. Scores were calculated by range personnel. The score is related to the probability that a war shot torpedo would cause lethal damage, given a specific entry location and identical conditions (i.e., aircraft track; submarine course, speed, and depth; and acoustic conditions). Flight-hour information was calculated from NAVFLIRS data.

C. ANALYSIS

1. Hypotheses

The central hypothesis of this analysis is that training improves performance. Thus, crew members with more career flight and simulator hours are expected to detect, locate and track the target with greater proficiency, and place their torpedoes more accurately. We also hypothesize that more recent flying and simulator experience, holding career training experience constant, is associated with more accurate attacks.

An additional hypothesis of interest is that crew stability enhances performance. However, because of the lack of complete data on when each member joined the crew, we were unable to test this hypothesis.

Table II-1. Data Used in the Analysis of Navy P-3 Torpex Missions

Variable	Minimum	Mean	Maximum
Score	9.9	19.4	23.9
Pilot Aircraft Commander Hours	26.0	747.6	3267.5
TACCO Mission Commander Hours	0.0	287.4	836.9
Pilot Flight Hours Previous 7 Days	0.0	6.5	24.1
Pilot Flight Hours Previous 30 Days	3.9	26.5	80.6
Pilot Flight Hours Previous 60 Days	3.9	54.7	140.5
Pilot Career Simulator Hours	29.4	111.6	292.0
Pilot Simulator Hours Previous 7 Days	0.0	1.0	6.0
Pilot Simulator Hours Previous 30 Days	0.0	3.1	17.0
Pilot Simulator Hours Previous 60 Days	0.0	5.3	25.2
TACCO Flight Hours Previous 7 Days	0.0	7.0	27.9
TACCO Flight Hours Previous 30 Days	0.0	27.6	92.2
TACCO Flight Hours Previous 60 Days	0.0	56.1	172.0
TACCO Simulator Hours Previous 7 Days	0.0	1.3	6.6
TACCO Simulator Hours Previous 30 Days	0.0	4.0	17.1
TACCO Simulator Hours Previous 60 Days	0.0	6.8	23.3
S1 Flight Hours Previous 7 Days	0.0	7.8	37.6
S1 Flight Hours Previous 30 Days	0.0	20.2	131.0
S1 Flight Hours Previous 60 Days	0.0	44.4	182.3
S1 Simulator Hours Previous 7 Days	0.0	1.3	6.6
S1 Simulator Hours Previous 30 Days	0.0	4.0	17.0
S1 Simulator Hours Previous 60 Days	0.0	6.9	24.0
S3 Flight Hours Previous 7 Days	0.0	7.4	29.8
S3 Flight Hours Previous 30 Days	0.0	32.4	121.7
S3 Flight Hours Previous 60 Days	0.0	61.2	182.7
S3 Simulator Hours Previous 7 Days	0.0	1.2	6.6
S3 Simulator Hours Previous 30 Days	0.0	3.5	16.2
S3 Simulator Hours Previous 60 Days	0.0	5.8	22.3
Percentage Actual SSN Targets		21.0	

2. The Model

a. The Cobb-Douglas Production Function Model

We postulate a log-log relationship based on the form of the raw data, our *a priori* beliefs about learning, and previous analyses of similar data. We expect learning to exhibit diminishing returns to increases in the experience variables. The estimating equation takes the following form:

$$\begin{aligned} \mathrm{LnScore} = {} & \mathrm{Lnb}_0 + b_1 \times \mathrm{LnH}_{pt} + b_2 \times \mathrm{LnH}_{pst} + b_3 \times \mathrm{LnH}_{tt} + b_4 \times \mathrm{LnH}_{pz} + b_5 \times \mathrm{LnH}_{psz} \quad (1) \\ & + b_6 \times \mathrm{LnH}_{tz} + b_7 \times \mathrm{LnH}_{tsz} + b_8 \times \mathrm{LnH}_{s1z} + b_9 \times \mathrm{LnH}_{s1sz} + b_{10} \times \mathrm{LnH}_{s3z} \\ & + b_{11} \times \mathrm{LnH}_{s3sz} + b_{12} \times \mathrm{SSN} \end{aligned}$$

where:

Ln = the natural log

Score = Torpex score assigned by range personnel

H_{pt} = pilot career flying hours

H_{pst} = pilot career simulator hours

H_{tt} = TACCO career flying hours

H_{pz} = pilot flying hours in the previous z days, where z = 7, 30, or 60 days

H_{psz} = pilot simulator hours in the previous z days, where z = 7, 30, or 60 days

H_{tz} = TACCO flying hours in the previous z days

H_{tsz} = TACCO simulator hours in the previous z days

H_{s1z} = S1 flying hours in the previous z days

H_{s1sz} = S1 simulator hours in the previous z days

H_{s3z} = S3 flying hours in the previous z days

H_{s3sz} = S3 simulator hours in the previous z days

SSN = a dummy variable taking the value one for an attack against an actual SSN (nuclear attack submarine) and 0 otherwise

b_0 through b_{12} = coefficients to be estimated

The coefficients b_1 and b_3 measure the effect on performance of additional pilot and TACCO career flying hours, respectively, holding career simulator hours constant. Both b_1 and b_3 are expected to be positive—more experience should be reflected in higher scores. The coefficient b_2 measures the effect on performance of additional pilot career simulator hours, holding career flying hours constant. We conjecture that scores will increase if simulator hours increase while holding flying hours constant. We therefore expect b_2 to be positive.

The coefficients b_4, b_6, b_8 and b_{10} measure the effect on the score of pilot, TACCO, S1, and S3 flying hours, respectively, in the previous 7, 30 or 60 days. We expect these coefficients to be positive. The coefficients b_5, b_7, b_9 and b_{11} measure the effect on the score of pilot, TACCO, S1, and S3 simulator time, respectively, in the previous 7, 30 or 60 days. We expect these coefficients to be positive as well. We cannot use two different short-term variables for the same crew position in the same equation because these variables are highly correlated. We might be able to use different short-term variables for different crew positions, since it is not clear that recently honed skills depreciate at the same rate for different crew positions.

SSN is a control variable. Missions flown against an actual SSN are considered to be more difficult than those flown against a simulated target. An SSN can take calculated evasive action throughout the exercise. We therefore expect b_{12} to be negative.

b. The Model With Interactions

In order to gain additional insight into the effect of experience on Torpex scores, we also formulated the model in the form of a generalized translog production function. We hypothesize that interactions exist between flying hours and simulator hours, and between long-term and short-term variables. The estimating equation then takes the form of equation (2). The terms in braces are the interaction terms. We have shown only 3 interaction terms for the sake of brevity, since there are as many possible combinations as there are pairs of terms in equation (1).

$$\begin{aligned} \text{LnScore} = {} & \text{Lnb}_0 + b_1 \times \text{LnH}_{pt} + b_2 \times \text{LnH}_{pst} + b_3 \times \text{LnH}_{tt} + b_4 \times \text{LnH}_{pz} + b_5 \times \text{LnH}_{psz} \quad (2) \\ & + b_6 \times \text{LnH}_{tz} + b_7 \times \text{LnH}_{tsz} + b_8 \times \text{LnH}_{s1z} + b_9 \times \text{LnH}_{s1sz} + b_{10} \times \text{LnH}_{s3z} \\ & + b_{11} \times \text{LnH}_{s3sz} + \{b_{1,2} \times \text{LnH}_{pt} \times \text{LnH}_{pst} + b_{6,7} \times \text{LnH}_{tz} \times \text{LnH}_{tsz} \\ & + b_{3,6} \times \text{LnH}_{tt} \times \text{LnH}_{tz} + \ldots\} + b_{12} \times \text{SSN}\ , \end{aligned}$$

where the definitions of terms are the same as for equation (1) and the $b_{i,j}$ are the coefficients of the interaction terms.

We expect the coefficients of the individual terms to be the same as for equation (1). The coefficients of the interaction terms are expected to be negative. The signs of the interaction coefficients correspond to the signs of the cross partial derivatives of score with respect to each variable in the interaction term. For example, we hypothesize that for higher levels of aircraft commander career flying hours, the marginal increase in score with increasing career simulator hours would be smaller, since more highly trained people are expected to gain less from additional training.

3. Methodology

Equations (1) and (2) were estimated using ordinary least squares. Because many of the minimum values of the independent variables are zero, a small constant was added to all independent variable observations. This is a commonly used Econometric technique and prevents the natural log from being indeterminate (minus infinity).

D. FINDINGS

1. Multicollinearity

The effect of changes in the pilot career simulator variable and the effect of changes in pilot career flying hours could not be estimated together because they are collinear. Pilots with more career flying hours tend to have more simulator hours as well. This means that the estimated effect of more flying hours includes the effect of additional simulator hours that usually go along with them. In addition, pilots with more career flying hours tend to have fewer recent simulator hours. We are unable to separate out the individual effects of these three variables. Perhaps this is not a serious problem. Although simulator events include coordinated tactical exercises, pilots concentrate on instruments, emergency procedures, and basic flying skills. Pilot simulator time is therefore not as directly related to torpedo attacks as is the simulator time of the remainder of the crew. Although we did find a significant statistical relationship between pilot simulator hours and Torpex scores, pilot career flight and simulator hours could not be estimated together. For estimated equations where career simulator hours are significant, the simulator variable acts (to some extent) as a proxy for flight hours.

In the case of the remaining TACNUC members, it was even more difficult to untangle the effect of flight and simulator hours on score. We had no long-term experience variables which might be useful in distinguishing the individual partial effects of the enlisted crew members. In addition, the TACCO, S1, and S3 participate together in nearly all simulator and flight events. The short-term flight and simulator variables are therefore highly correlated across individuals. In order to try to draw some meaningful conclusions, we searched for a variable which would serve as a proxy for the short-term experience of the TACCO and enlisted sensor operators as a team.[2]

2. Variables Used in the Estimating Equations

The pilot and TACCO career experience variables used in the estimating equations are Aircraft Commander and Mission Commander hours, respectively. The short-term variables used in the equations are S1 flying hours in the previous 60 days and S1 simulator hours in the previous 30 days. Recent flying hours for the pilot and TACCO were not found to be significant, and are omitted from the final equations. The S3

---

[2] See any standard Econometrics text for a discussion of the effects and possible solutions to the multicollinearity problem. The direction we have taken is to drop some of the variables and accept the remaining variables as proxies for those not included in the equation.

variables could not be estimated in the same equation with the S1 variables, and the S1 effects were much more significant than the S3 effects alone. This is not surprising because the S1 plays a more important role in this particular exercise. None of the interactions between flight hour and simulator variables were statistically significant. However, the interaction between TACCO mission commander hours and S1 flying hours in the previous 60 days could be estimated. The estimated coefficients of equations (1) and (2) using this set of variables are reported in Table II-2.

Table II-2. Determinants of P-3 Torpex Performance

Dependent Variable: Ln Score Independent Variable	Coefficient Equation (1)	 Equation (2)
Intercept	2.60 (16.2)***	2.59 (16.5)***
Ln of total pilot aircraft commander hours (H_{pt}).	0.0385 (1.68) *	0.0364 (1.65)
Ln TACCO total mission commander hours(H_{tt})	0.0168 (1.49)	0.0325 (2.39)**
Ln S-1 flight hours previous 60 days (H_{s1f60})	0.0224 (1.98)**	0.0420 (2.82)***
Ln S-1 simulator hours previous 30 days (H_{s1s30})	0.0186 (2.241)**	0.0170 (2.10)**
TACCO career mission commander-S-1 60-day flight hour interaction (Ln $H_{tt} \times$ Ln H_{s1f60})		-0.0067 (1.95)*
Submarine target dummy variable	-0.0733 (1.14)	-0.0797 (1.28)
Number of Observations	53	53
Adjusted R-square	.27	.31
Equation (2) H_{tt} elasticity		0.0231
Equation (2) H_{s1f60} elasticity		0.0039

Note: Numbers in parentheses are t-statistics.
* Significant at the 0.10 level.
** Significant at the 0.05 level.
*** Significant at the 0.01 level.

3. Elasticities of Score With Respect to Variables Used in the Equations

The results shown in Table II-2 are consistent with all of the hypotheses discussed above. All of the coefficients have the expected sign. All of the coefficients in equation (1) except for TACCO career mission commander hours and the SSN dummy are significant at the 0.10 level of significance or better using a two-tailed test. The TACCO career mission commander hours coefficient is significant at the 0.14 level. The SSN

dummy is a control variable, and our primary interest is that the sign be as expected. All of the coefficients in equation (2) except for Pilot Career Aircraft Commander hours and the SSN dummy are significant at the 0.10 level or better using a two-tailed test. The Pilot Career Aircraft Commander hours coefficient is significant at the 0.1081 level.

Equations (1) and (2) explain respectively only 0.27 and 0.31 of the variation in Ln Score. However, the R^2s are above the norm relative to other studies which analyzed this type of detailed cross-sectional flying hour data. These R^2s are comparable to those obtained for our Marine Corps bombing analysis [2]. This percentage of explained variation means that the equations cannot precisely predict a given Torpex score based on the explanatory variables in these equations. The goal of this paper is not, however, to predict individual scores. Rather, it is to estimate the effect of variations in training experience on the average scores of a population on a large number of exercises. The statistical significance of the flying and simulator hour coefficients indicates that it is adequate for this purpose and, therefore, for setting policy on flying and simulator hours.

Because the equations were estimated in log-log form the coefficients are estimated elasticities. Elasticity is the percentage change in the crew's score with a 1% change in the independent variable. For the variables that appear in the interaction term, the elasticity must be calculated using the coefficient of the interaction term and the average values of the independent variables, as well as the coefficients of the terms involving the individual variables.

Table II-3 shows the estimated elasticities and partial effects of the experience variables for equation (2) calculated at the mean. The partial effect is the change in the dependent variable with a unit change in the independent variable. For example, if S1 flight hours in the previous 60 days were to change by 1 hour we would expect Score to change by 0.002.

Table II-3. Elasticities and Partial Effects of Torpex Scores With Respect to the Experience Variables (Equation 2)

Independent Variable	Elasticity	Partial Effect
Pilot Career Aircraft Commander Hours (H_{pt})	0.0364	0.0011
TACCO Career Mission Commander Hours (H_{tt})	0.0231	0.0018
S1 Flight Hours in Previous 60 Days (H_{s1h60})	0.0039	0.0020
S1 Simulator Hours in Previous 30 Days (H_{s1s30})	0.0170	0.0961

4. Graphical Representation of the Results

The effects reported in Table II-2 are shown graphically over the full range of the data in Figures II-1 through II-4.[3] These graphs depict the effect of changing each experience variable while holding all other variables constant. In all cases the independent variables which are not being examined are held at their observed means.[4] All of the graphs show that the marginal improvement for an additional flying or simulator hour is greater for crewmen with less experience. This is the expected result and is a characteristic of the functional form. Functional forms that did not exhibit this characteristic did not fit the data as well.

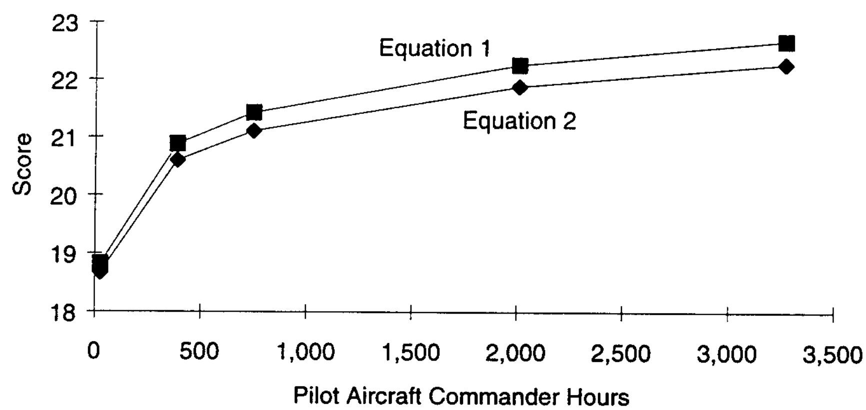

Figure II-1. P-3 Torpedo Attack Score Versus Pilot Career Aircraft Commander Hours

---

3 In Figures II-1 through II-4, the first, third, and fifth values are the minimum, mean, and maximum observed values, respectively. The second and fourth points are the mid-points between those values. In cases where the minimum value is zero, a small constant was added to prevent the predicted value of the dependent variable from being indeterminate (minus infinity).

4 In order to graph the estimated equation we made the transformation:

$$\text{Score} = \exp\{\text{Ln Score}\} = \exp\{\Sigma_i b_i x_i\}.$$

However, this is a biased estimate of Score because the mean of the transformed residual, which is non-zero, is omitted. For Ln u_i distributed $N(0,s^2)$, u_i is distributed log-normal with mean $\exp\{0+(s^2/2)\}$. We therefore include the correction $\exp\{s^2/2\}$ where s is the estimated standard deviation (root mean square error). The transformed equation is:

$$\text{Score} = \exp\{\text{Ln Score}\} = \exp\{\Sigma_i b_i x_i\} \exp\{s^2/2\}.$$

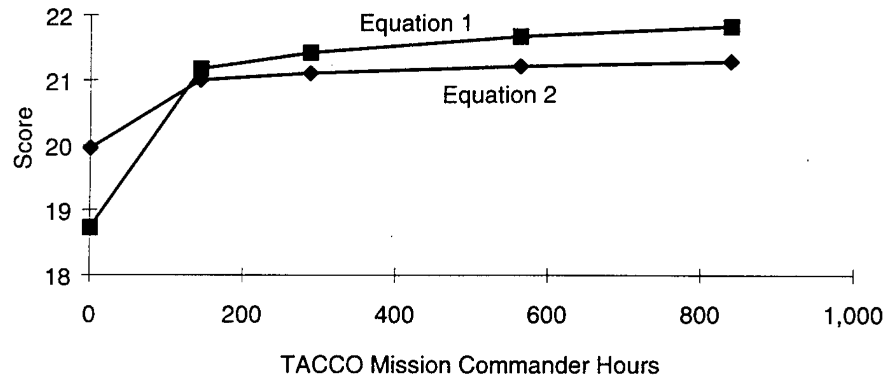

Figure II-2. P-3 Torpedo Attack Score Versus TACCO Career Mission Commander Hours

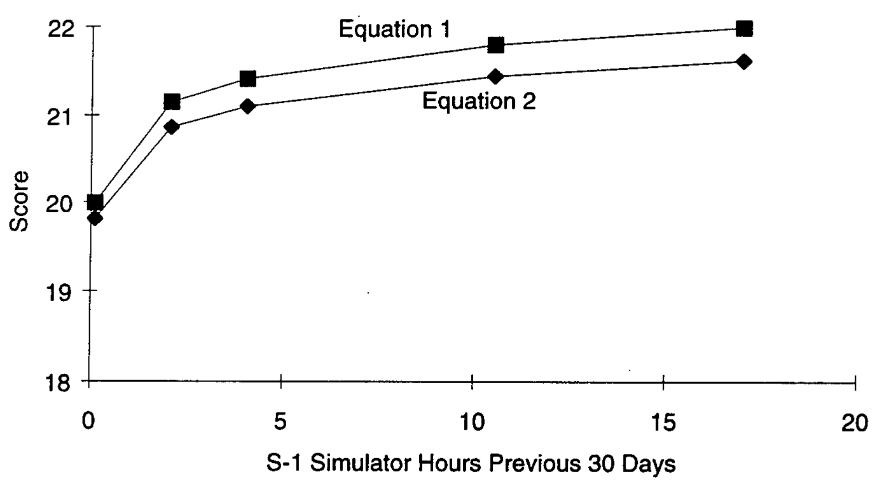

Figure II-3. P-3 Torpedo Attack Score Versus S-1 Simulator Hours in the Previous 30 Days

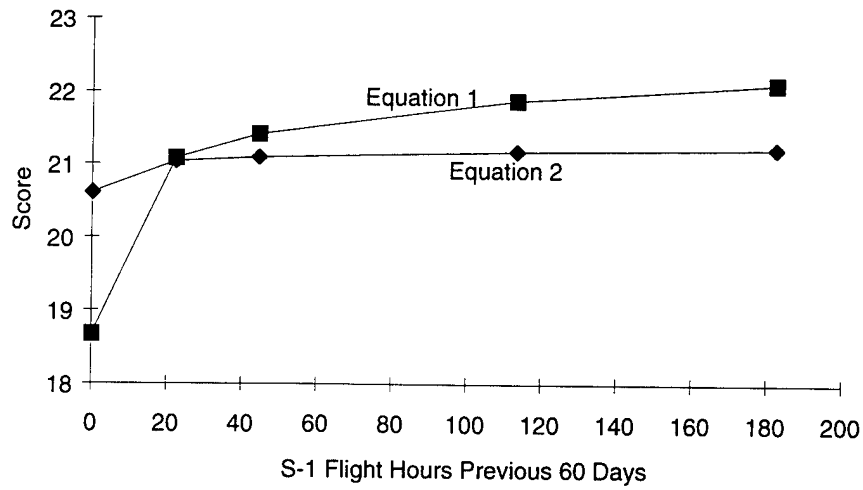

Figure II-4. P-3 Torpedo Attack Score Versus S-1 Flying Hours in the Previous 60 Days

E. SUMMARY

The findings indicate that flying and simulator hours in the short-term and flying hours in the long-term have a significant effect on Torpex performance. Career flying hours for the aircraft commander and TACCO have greater percentage effects on Torpex scores than the short-term variables. This has been a consistent finding in past studies. Because of data limitations, we were unable to estimate the long-term effects for the enlisted crew members.

Because of the nature of the Torpex exercise, the findings are also applicable to a greater part of the full mission than previous studies, other than our analysis of air-to-air combat exercises. For example, our analysis of Marine bombing, reference [2], examined only the bombing run and delivery, and did not address success in reaching or egressing from the target area. Torpex scores reflect the crew's success in detecting, classifying and tracking the target, and the accuracy of the weapon delivery.

On the margin, the partial effect of recent simulator hours is greater than for the short-term flying hour variables. Since simulator hours are less expensive than flying hours, this implies that simulator hours are cost-effective. This effect may apply only to small changes near the observed mix of flying and simulator hours. The effect of larger increases in simulator hours, especially when combined with decreases in flying hours, cannot be discerned from our analysis.

Because of multicollinearity, we were unable to disentangle the effects of all of the variables; however, we were able to sort out the short-term variables in terms of the total crew. In other words, the significant results for the S1 short-term flying hour and simulator variables may proxy for the TACCO, S1, and S3 as a crew. We, of course, cannot state this as a fact because the S1 is a key crew member throughout the detection, classification, tracking, and attack phases of the exercise. The effect we observed could be attributable to the S1 alone.[5]

The estimation problem is partly a result of the way in which crews train, but to a great extent this is a data collection problem. The VP crews fly many graded competitive exercises during each training cycle. The scores for these exercises are recorded along with the squadron and crew number. However, the records needed to identify the individual members of the crew are kept only for approximately 9 months, and those that are retained are sporadic for periods earlier than the most recent 2 or 3 months. Torpex exercise data were selected for this analysis because we were able to reconstruct the Torpex crews from flight records and a scattering of crew lists. The crews fly to a Naval Air Station near the range prior to each exercise, and with this information we could identify the aircraft and crew members. However, we could identify the crew positions for only about a year's worth of data. This greatly limited the number of available observations. In general, graded exercise score data do not identify the aircraft or the individual crew members, so it was impossible to identify the crew members from NAVFLIRS data for exercises other than Torpexes. Additional data could have another beneficial effect, since some competitive exercises, other than Torpedoes, are flown while squadrons are deployed. Simulators are not available to deployed squadrons, so these exercises could produce smaller correlations between the short-term flying and simulator hour variables. A second serious data problem is the lack of a complete record of enlisted career flying hours.

Based on these results, we can make some quantitative statements with respect to short-term experience for the crew and long-term experience for the aircraft commander and TACCO crew positions. Based on the estimated coefficients for equation (2), if the number of flying hours were reduced by 10% for a short period of time the average Torpex score would decrease by 0.04%. A similar decrease in crew simulator hours

---

5 We also experimented with linear combinations of the short-term variables for these crew positions with mixed results. Linear combinations of the TACCO and S1 short-term simulator and flying hour variables were highly significant, but the coefficients could not be estimated accurately with the pilot and TACCO career hours.

would result in a decrease of approximately 0.2%. If the decrease in flying hours continued until pilot and TACCO career experience degraded by 10%, then Torpex scores would decrease an additional 0.6%, the sum of the AC and TACCO coefficients multiplied by 10. We cannot predict the total long-term effect because of the absence of enlisted career flying hour data. Table II-4 summarizes these results.

Table II-4. Decrease in Performance (Torpex Score) for 10% Decrease in Three Measures of Flying/Simulator Experience

	Career Flying Hours	Recent Flying Hours	Recent Simulator Hours
Pilot Aircraft Commander	0.4%	—	—
TACCO Mission CDR	0.2%	—	—
First Acoustics Operator	—	0.04%	0.2%[a]
Total	0.6%	0.04%	0.2%

[a] Because the TACCO, First Acoustics Operator and Electronics Operator fly and exercise in the simulator as a crew the short-term effects of these three could not be estimated together. We interpret the results for the First Acoustics Operator as the crew effect.

The data used in this study reflect operations before the collapse of the Soviet Union, when maritime patrol squadrons averaged approximately 45 flying hours per month per crew over the entire 18-month training cycle. This has been reduced to as little as 30 hours per month. We would expect the quantitative findings to be different for current data.

The above effects are difficult to interpret because we do not know the effect of a percentage decrease in average Torpex scores. Although the range of scores in our study was 14, the minimum score was 3 standard deviations below the mean of 19.4, and most of the observations were bunched near the mean. A decrease in the mean score of 1% might represent more or less than a 1% decrease in submarine kills.

III. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Existing data on performance can be used to develop relationships between air crew performance and both long- and short-term experience variables that reflect the impact of variations in the flying hour program. This analysis is important because it demonstrates our ability to estimate the effect of flying and simulator hours on performance over nearly the full range of the maritime patrol mission—detection, classification, tracking, and attack.

The following conclusions can be drawn from this analysis.

- Maritime patrol Torpex scores are influenced by the number of career aircraft commander hours of the pilot, mission commander hours of the TACCO, and recent flying hours of the acoustic operator.
- Recent acoustic operator simulator hours influence Torpex scores significantly, and simulator hours appear to be cost-effective.
- The long-term effects are quantitatively more important than short-term effects. This is consistent with previous analyses (see references [1] and [2]) and has important policy implications during a period of shrinking force structure and budgets. This finding implies that it may be unwise to reduce overall air crew experience with the thought that, when needed, crews can be brought to full effectiveness with a short period of intensive training.
- A 10% reduction in flying hours, both career and recent, is estimated to decrease Torpex scores by a little more than 0.6%.
- Although we were unable to completely disentangle the individual effects of each member of the TACNUC, we were able to separate the long-term effects of the pilot and TACCO from the short-term effects of the TACCO and enlisted crew members. With a more complete data set we believe that more meaningful results, particularly the long-term effects of the training given enlisted crew members, are obtainable.
- It would appear to be worthwhile to analyze the data generated under the current flying hour levels. It is too great a leap to extrapolate our findings to a 33% decrease in flying hours (45 to 30 hours per month per crew). An experiment using current data could greatly increase our understanding of the effect of marginal changes in career flying hours and both short-term flying

and simulator hours on Torpex scores. A more complete data set would be available provided the assistance of the wing and squadrons was enlisted for a period of approximately one year. With more complete records, including enlisted career flying hours and a complete record of crews for every competitive exercise, many of the problems with the current data could be eliminated. In particular, if we had a complete record of when each member joined the crew, we could test the hypothesis that crew stability enhances performance. Other data problems, such as the lack of career TACCO and enlisted simulator hours, would require a major change in Navy record keeping procedures over a longer period of time.

This study is highly complementary to the work reported in references [1] and [2] because it treats a multi-person aircraft and because it treats nearly the entire mission of the aircraft. Once again an analysis of objective data has shown that reductions in flying hours will lead to degradations in performance.

The findings are consistent with earlier work, but they also indicate that the database should be updated and expanded for the following reasons:

- The findings could be strengthened by an increase in both the number of observations and the variety of exercise types.
- The lack of career flying hours for the enlisted crew members seriously limits the completeness of the analysis.
- Recent decreases in average monthly crew flying hours could dramatically change the implications of these findings with regard to the effect of marginal changes in both flying hours and simulator hours.

The kinds of relationships developed in this paper do not, by themselves, answer the increasingly urgent questions posed by recent and on-going defense budget reductions. Neither we nor other researchers have adequately addressed the cost-effectiveness of flying hour reductions. Savings in flying-hour budgets may result in higher costs in other areas in peacetime or they may have adverse affects in wartime.

For example, the peacetime cost of reduced training should include the planes and pilots that might be lost because of increased accident rates. A recurring observation made by air crewmen throughout this series of studies is that they must fly with some minimum frequency, which they perceive as necessary for safety, or they will not remain in the service. Reduced air crew retention increases personnel acquisition and training costs.

Wartime costs involve the possibility of less favorable combat outcomes because of reduced pilot proficiency. Analyses based on the use of constructive simulations of warfare could give greater insight into the possible magnitude of these costs.[1]

The importance of aggregate career training experience indicates that a more experienced force is a readier force. It seems clear that extended tours in staff and management billets decrease average career flight experience. Further analysis is needed to address the implications of the results of this (and related) studies for some key force and career management policy issues, such as:

- What the average career experience level should be; how much training is enough?
- How to maintain the proper balance of operational skills, officer education and leadership training.
- How to better use the reserve component—which has more experienced pilots—to attain the best mix of operational and administrative skills.

B. RECOMMENDATIONS

We recommend that controlled experiments be conducted and a more complete database constructed to perform the following:

- Studies designed to gain a better understanding of the cost-effectiveness implications of changes in flying hour budgets for different missions, aircraft types, and crew positions.
- Analyses aimed at further documenting the marginal effects of changes in simulator and actual flying hours on performance at current and projected levels.

To better understand the full potential costs of reduced air crew training, the results of studies such as this one should be incorporated into combat analyses.

Our final recommendation is to consider the following policy actions:

- Moving to a more senior mix of personnel. This could involve encouraging longer careers, perhaps by modifying retirement policies and incentives.
- Keeping individuals with hard-to-train operational skills, such as pilots, in operational billets as much as possible, consistent with the need for trained and educated leaders.

---

1 Some preliminary work of this type has been performed and is available in briefing form from the authors under the title, "The Cost-Effectiveness of Flying Hours and Simulation."

- Making use of experienced personnel through maximum practical reliance on the reserve components (particularly in aviation).

REFERENCES

REFERENCES

[1] Hammon, Colin P., and Stanley A. Horowitz. "Flying Hours and Aircrew Performance." Institute for Defense Analyses, Paper P-2379, March 1990.

[2] Hammon, Colin P., and Stanley A. Horowitz. "Relating Flying Hours to Aircrew Performance: Evidence for Attack and Transport Missions." Institute for Defense Analyses, Paper P-2609, June 1992.

ABBREVIATIONS

ABBREVIATIONS

AC	Aircraft Commander
COMPEX	Competitive Exercise
ECM	electronic countermeasures
EXTORP	exercise torpedo
MAD	Magnetic Anomaly Detection
NAVFLIRS	Naval Flight Information Reporting System
NFO	Naval Flight Officer
REXTORP	torpedo shape
S1	first acoustic operator
S2	second acoustic operator
S3	electronic warfare operator
SSN	nuclear attack submarine
TACCO	Tactical Coordinator
TACNUC	Tactical Nucleus
Torpex	Torpedo Exercise
VP	designation for patrol aircraft

UNCLASSIFIED

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY (Leave blank)

2. REPORT DATE
December 1996

3. REPORT TYPE AND DATES COVERED
Final, Sep 1992–Dec 1996

4. TITLE AND SUBTITLE
The Relationship Between Training and Unit Performance for Naval Patrol Aircraft-Revised

5. FUNDING NUMBERS
DASW01 94 C 0054

T-L7-516

6. AUTHOR(S)
Colin P. Hammon and Stanley A. Horowitz

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Institute for Defense Analyses
1801 N. Beauregard Street
Alexandria, VA 22311-1772

8. PERFORMING ORGANIZATION REPORT NUMBER
IDA Paper P-3139, Revised

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
John Walsh
Office of the Deputy Under Secretary of Defense (Readiness)
Room IC757, The Pentagon
Washington, DC 20301

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES
Supercedes IDA Paper P-3139

12A. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for Public Release; distribution unlimited.

12B. DISTRIBUTION CODE

13. ABSTRACT ***(Maximum 200 words)***

This report develops quantitative relationships between how much air crews train and how well they perform important aspects of their missions. It examines the performance of Navy Patrol air crews in the P-3 aircraft. The performance data were derived from graded torpedo exercises flown on an instrumented range. The crew must detect, classify, track, and successfully launch an exercise torpedo to qualify in the exercise. The P-3 carries a multi-person crew, including a pilot, tactical coordinator (both officers), and enlisted sensor operators. We gathered data covering both the long-term and short-term training experience of crew members and considered training both in the aircraft and in simulators. Statistical analyses were performed to estimate relationships between training and performance. The analyses showed both short- and long-term positive effects of flying hours on air crew performance. Long-term experience was more important. Although data on long-term simulator use were not available, recent simulator experience was found to be particularly cost-effective.

14. SUBJECT TERMS
Performance (Human); Flight Crews; Naval Aircraft; P-3 Aircraft; Patrol Aircraft; Flight Training

15. NUMBER OF PAGES
33

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	SAR

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

UNCLASSIFIED